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Dated 27 November 2003

Patents Form 1/77

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28MAR03 E795924-1 D10153
P01/7700 0.00-0307160.2

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Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office

Cardiff Road
Newport
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NP10 8QQ

1. Your reference — P169-GB

2. Patent application number *(The Patent Office will fill in this part)* — 0307160.2

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

   1... Limited
   St John's Innovation Centre
   Cowley Road
   Cambridge CB4 0WS

   Patents ADP number *(if you know it)* — 8113870001

   If the applicant is a corporate body, give the country/state of its incorporation — England

4. Title of the invention — CERAMIC ACTUATOR AND LOUDSPEAKER

5. Name of your agent *(if you have one)* — Akram K. Mirza

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

   1... Limited
   St John's Innovation Centre
   Cowley Road
   Cambridge CB4 0WS

   Patents ADP number *(if you know it)* — 8113870001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
   a) any applicant named in part 3 is not an inventor, or
   b) there is an inventor who is not named as an applicant, or
   c) any named applicant is a corporate body.
   See note (d))

   YES

Patents Form 1/77

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	0
Description	7
Claim(s)	2
Abstract	1
Drawing(s)	5 only

10. If you are also filing any of the following, state how many against each item.

Priority documents

Translations of priority documents

Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*

Request for preliminary examination and search *(Patents Form 9/77)*

Request for substantive examination *(Patents Form 10/77)*

Any other documents *(please specify)*

11. I/We request the grant of a patent on the basis of this application.

Signature

Date 28-MAR-03

12. Name and daytime telephone number of person to contact in the United Kingdom Akram K. Mirza 01223-422290

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After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

a) *If you need help to fill in this form or you have any questions, please contact the Patent Office on 08459 500505.*

b) *Write your answers in capital letters using black ink or you may type them.*

c) *If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.*

d) *If you have answered 'Yes' Patents Form 7/77 will need to be filed.*

e) *Once you have filled in the form you must remember to sign and date it.*

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P169-GB

CERAMIC ACTUATOR AND LOUDSPEAKER

FIELD OF THE INVENTION

The present invention relates to loudspeaker systems for portable electronic devices such as mobile phones, personal digital assistants (PDAs) and laptop computers. More specifically, it relates to a method and system for generating low frequency or vibratory signals and higher acoustic frequency or audible signals. Furthermore it relates to such systems driven by actuators based on piezoelectric materials.

BACKGROUND OF THE INVENTION

In mobile communication and data processing equipment, the generation of audible sound, buzz tones or vibration are handled by systems mostly driven by electro-magnetic actuators.

Sound is usually generated by, albeit small, voice-coil driven loudspeakers, whereas number of reasonably inexpensive and effective constructions have evolved for providing signal units to generate the necessary tones or vibrations for these devices. These include miniature motors with imbalanced rotors to create a sensible vibration; small piezoelectric assemblies to vibrate at an audio frequency and create a tone or beep ("buzz") noise; and other, older technologies such as speakers with an electromagnetic voice coil, or a magnetic solenoid driving a diaphragm to create a sound such as an audio tone or a vibratory buzz. Many of the current mobile phones use separate components for vibration alert, audio alert and speech or music reproduction.

Also, it is desirable for most portable devices to a have a "hands-free" mode, i.e., a mode that allows a user to communicate through the device without having to use his or

her hands. In order to operate portable phones in a hands-free mode, a high power output is required over a frequency range of 300 to 3400 Hz, often referred to as the speech band. At present the hands-free mode of commercially available products is exclusively implemented through common electro-dynamic or moving coil loudspeakers.

A number of piezoelectric alerting devices have been proposed to generate a vibration or non-audible alert or audio frequency vibration and, thus, constituting a speaker. Examples of such devices are described in the United States Patent Nos. 5,514,927; 5,368,456; 6,078,126 and 6,169,206.

In the commonly-owned published international patent application WO-03/001841, which is incorporated herein by reference, there are described various devices and methods to generate sound comprising a support on which is mounted an electro-active actuator, which is in turn coupled to an area-extensive section of the case of the device, which section of the case acts as the sound generating element of a loudspeaker. In embodiments illustrated therein the sound generating element is driven in operation by an electro-active actuator preferably acting upon an edge of the sound generating element. The actuator described is a flat ceramic bender curved into an almost tubular shape.

It is the purpose of the present invention to provide a improved electro-active drive unit for loudspeaker for use in for example electronic devices, particularly portable electronic devices such as mobile phones

SUMMARY OF THE INVENTION

Accordingly, in a first aspect the present invention provides a loudspeaker for a possibly portable electronic device such

as a mobile phone which comprises a support on which is mounted one or more electro-active actuators, which is in turn coupled to an area-extensive section of the case of the device, which section of the case acts as the sound generating element of the loudspeaker, wherein the actuator or actuators include a curved section and at least one flat section.

The curved section is preferably formed having a hollow cylindrical shape with one sector extending along the longitudinal axis of the cylinder being removed. Hence a cross-section perpendicular to the longitudinal axis is a section of a circle or in other words C-shaped. At the longitudinal extending ends the curved section into one or more flatter sections that provide contact or mounting points to mount the actuator onto the support structure. A perpendicular cross-section through flat and curved section of the actuator thus resembles a flat-lying question mark or the Greek letter Ω, depending on whether a flat section terminates one or both ends of the curved section.

It is advantageous to provide flat sections to facilitate the mounting of the ceramic actuator onto support structure or sound generating surface or both.

However, an additional advantage is seen in providing an curved actuator that has sections at which the curvature of the material changes from inward bowing (concave) to flat or outward bowing (convex).

These and other features of the inventions will be apparent from the following detailed description of non-limitative examples making reference to the following drawings, throughout which like parts are designated by like reference numerals and characters.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1A is a perspective top view of an actuator in accordance with an example of the invention;

FIG. 1B shows a cross section through the actuator of FIG. 1A;

FIG. 2 is a perspective top view of a variant of the novel actuator;

FIG. 3 is a perspective top view of another variant of the novel actuator; and

FIGs. 4A,B illustrate a loudspeaker driven by an actuator as shown in FIG. 1.

DETAILED DESCRIPTION

In FIG. 1A, there is shown a perspective view of the novel actuator **10**. The main elements of the actuator include a convex curved section **11**. The single convex section **11** changes curvature to form an intermittent concave section **12** before extending gradually and continuously into an essentially flat section **13**. The actuator **10** is manufactured from multi-layered ceramic tape **101** with layers of ceramic PZT separated by layers of electrodes (not shown). The numbers of such layers are determined by the manufacturing process and can range from two ceramic (PZT) layers to more than ten.

The tape can be produced in accordance with well known manufacturing techniques. In its green state, it is then cut and pressed onto a suitable former to give it the form shown in FIG. 1A. Then the tape is burned out and sintered at high temperatures (600 to 1200 degrees Celsius). Outer electrodes may be applied after the sintering. After a poling step the actuator is ready to be mounted onto a chassis. These manufacturing steps are known per se and are regarded to be well within the scope of person skilled in the art.

A schematic cross-section through the actuator **10** of FIG. 1A along the line AB is shown in FIG. 1B. The first curved section **11** is convex, whilst the second section **13** is essentially flat. Between the two sections, there is a portion **12** where the curvature changes from convex to concave. The convex and concave portions of the actuator are indicated by dashed circles reflecting their respective main radii R1 and R2 of curvature. The multi-layered tape making up the actuator acts essentially as a bender with different portions moving in different directions as indicated by arrows in FIG. 1B. As the first curved section **11** moves essentially radial, the flat portion **13** and the intermediate concave portion **12** move upwards. The combined motion of the distal end **111** of the actuator is indicated by arrow **14**. It is an essentially vertical movement with lesser components of the motion in undesired tangential directions compared to known actuators such as the C-shaped actuator of WO-03/001841. The rotational displacement of the known C-shaped actuator of WO-03/001841 is similar to the motion of the first curved section **11**, however in the case of the novel actuator **10** it is partly cancelled by the concave section **12**, resulting in an improved or "purer" vertical displacement of the distal end **111**.

The example of FIG. 2 shows a variant of the previous example modified in that the flat section **23** includes two tabs or lead-outs **231**. In other words, a rectangular section is cut out of the flat portion **23**, thus reducing the amount of active material necessary to implement the actuator **20** while at the same time preserving the advantageous properties of the novel actuator design as described herein. Thus, other elements **21**, **22** of the actuator and its motion and displacements of the actuator of the present example is essentially identical to those illustrated in FIG 1B above.

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The two tabs **231** provide a sufficiently large area to mount the actuator onto a flat surface and electrical terminals to connect the actuator to an electronic drive circuit and power supply.

For some applications, it may be useful in and advantageous to terminate the distal end of the actuator with the second flat portion. This second flat portion, though not contributing significantly to the displacement, could facilitate the mounting of the distal (moving) end of the actuator onto an movable object such as a loudspeaker diaphragm.

In FIG. 3 such an actuator **30** is shown. In addition to the convex section **31**, the flat section **33** and the intermediate portion **32** shared with the above examples, the actuator **40** has a flat portion **34** at it distal end.

In FIG. 4, the actuator of FIG. 1 is shown used as a drive unit **40** to drive a rectangular diaphragm **44** within the housing **45** of a mobile device. The diaphragm material is Perspex™ (poly methylene methacrylate). The diaphragm **44** rests within a recess of the housing so as to be mounted flush with the outer surface of the housing **45**.

The gap between the housing **45** and the diaphragm **44** is sealed off by means of a compliant gasket **46** shown in FIG. 4B which is a cross-section of the perspective view of FIG. 4A along the line AB. It The gasket **46** prevents the entry of dust or humidity. It is made of Poron (TM), a cellular urethane based sealing material. The actuator **40** bridges the gap between the housing **45** and the diaphragm **44** at one short side of the rectangular diaphragm. The flat portion **43** of the actuator is mounted onto the housing while the curved portion **41** spans the sealed gap. The distal end **411** of the actuator is glued onto the diaphragm material **44**.

When an operating voltage is applied to the actuator **40**, the displacement drives the edge of the diaphragm **44** which in turn generates audible sound.

The larger contact area between the actuator **40** and the housing **45** together with the improved displacement of the actuator generate a higher sound level and an improved performance of the device as a loudspeaker compared to known devices such as described in WO-03/001841.

CLAIMS

1. Loudspeaker for audible sound comprising a sound emitting element mounted onto a support structure and at least one ceramic bender-type actuator being mounted at a proximate edge onto said sound emitting element and a distal edge onto said support structure, wherein the actuator comprises a first curved section extending radially into a second, essentially flat section.

2. The loudspeaker of claim 1 having a compliant sealing element or elements around the edges of the sound-emitting element.

3. The loudspeaker of claim 1 wherein the second flat section with the distal edge is mounted onto a part of the support structure while the first curved section with the proximate edge is mounted onto the sound-emitting element such that said curved section bridges a gap between said sound emitting element and said support structure.

4. The loudspeaker of claim 1 wherein the support structure and the sound generating element are parts of the outer shell of a portable data handling or communication device.

5. The loudspeaker of claim 1 wherein the second flat section extends in a longitudinal direction into a rectangular shape.

6. The loudspeaker of claim 1 wherein the second flat section terminates as two or more flat portions.

7. Ceramic actuator comprising a first curved section extending radially into a second, essentially flat section.

8. The ceramic actuator of claim 7 having a single curved section bowed inwardly with a short outwardly bowed portion that extends into the flat section.

9. The ceramic actuator of claim 7 formed from a continuous sheet of piezoelectric material.

P169-GB

ABSTRACT

A loudspeaker for audible sound, and a drive unit, is described having a sound-emitting element mounted onto a support structure and ceramic actuator made of piezoelectric material that includes a curved portion that extends radially into an essentially flat section.

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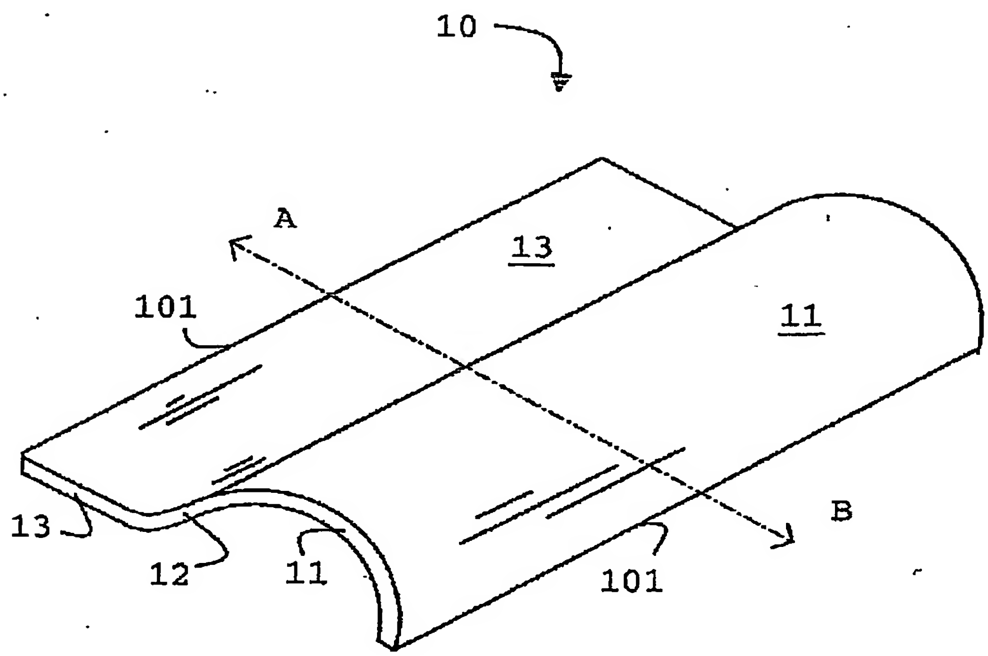

FIG. 1A

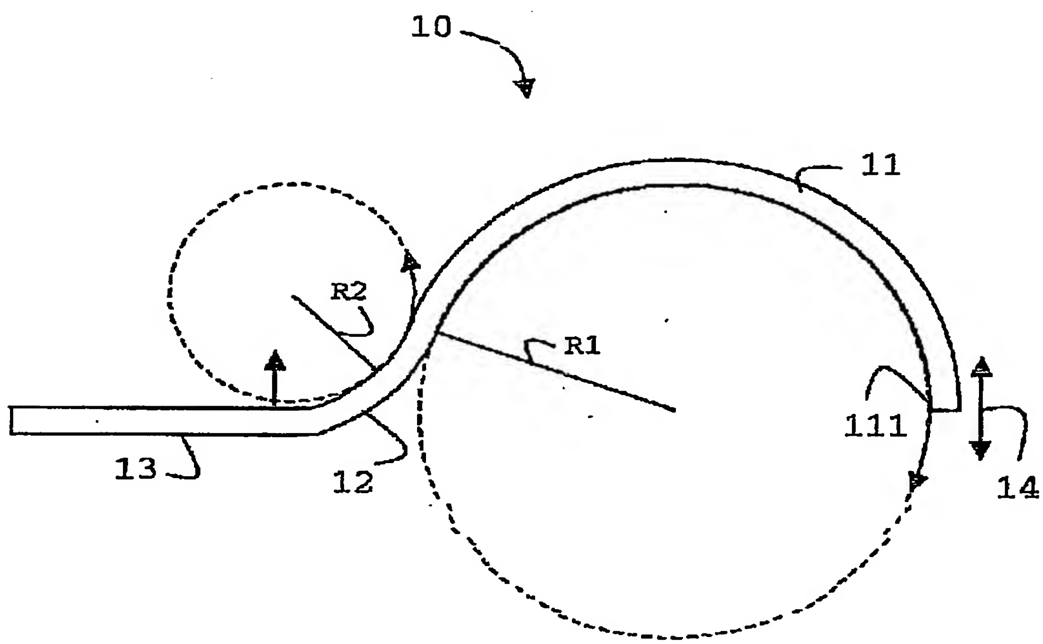

FIG. 1B

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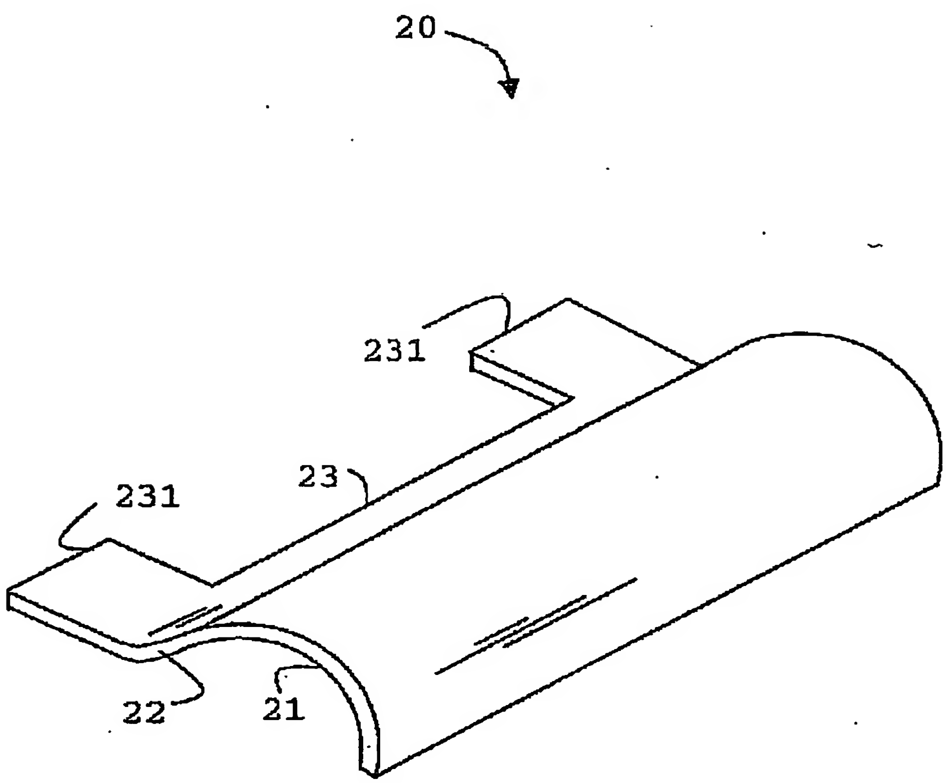

FIG. 2

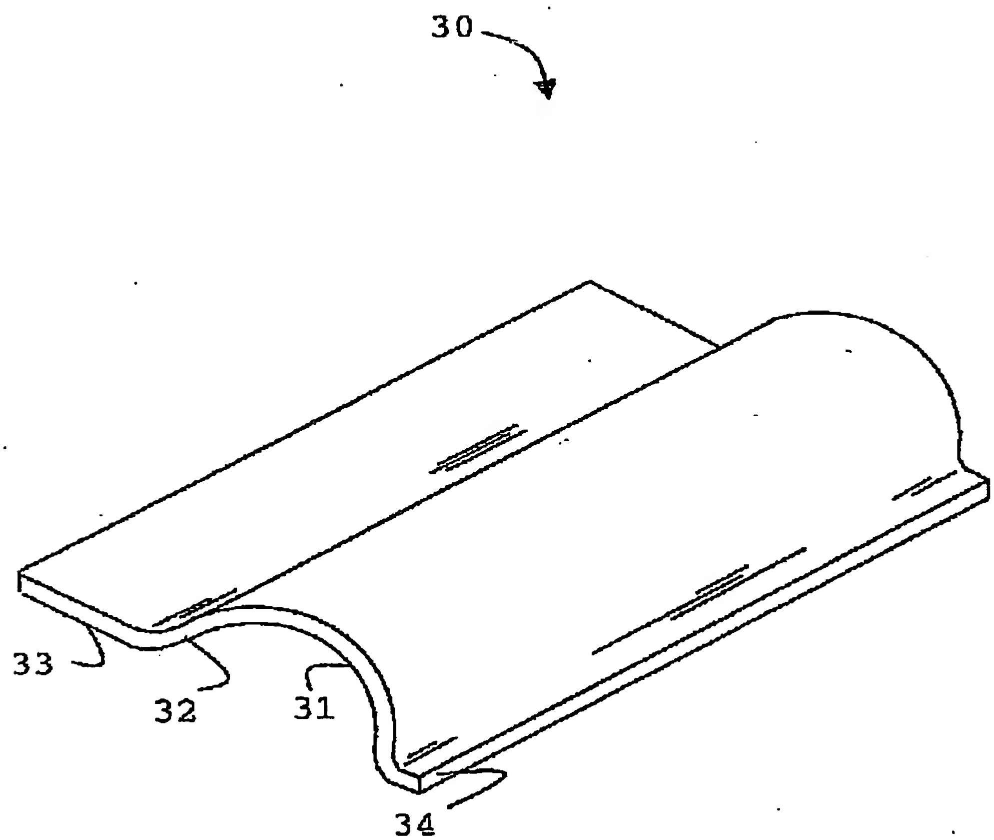

FIG. 3

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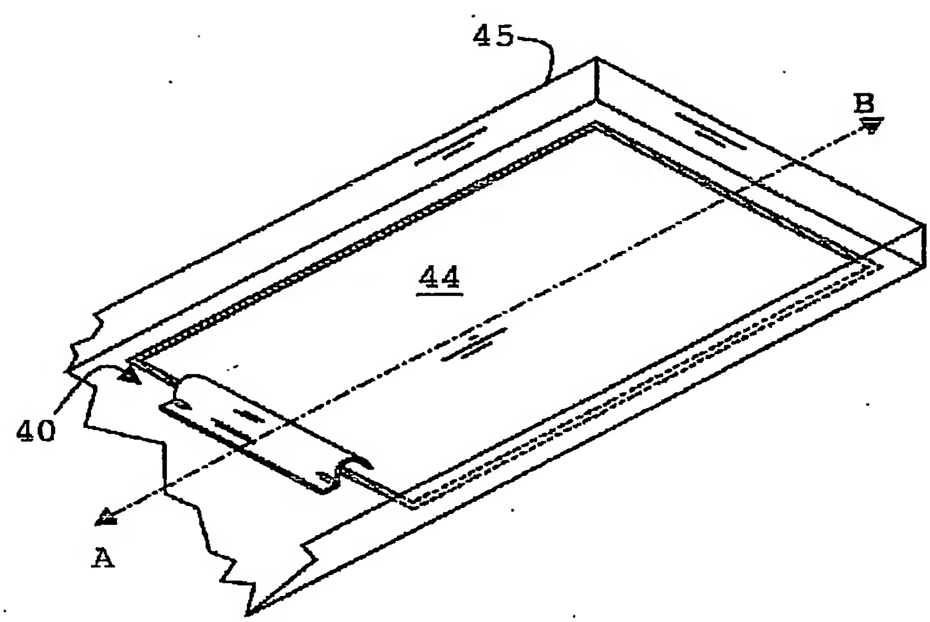

FIG. 4A

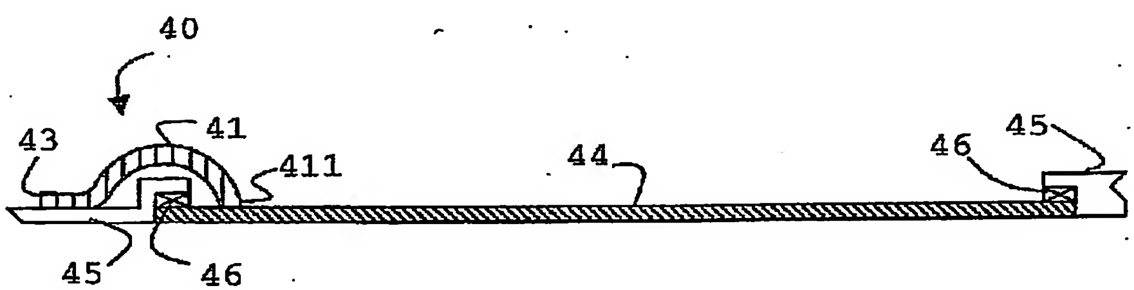

FIG. 4B